Test Report on
Solar Diffusion of Painted Reflectors

April 26, 1995

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1.0 Introduction

The specification document for the GBT requires use of Triangle 6 paint on the main reflector and subreflector surface panels. This paint has been used on most other NRAO antenna surface panels, and is widely used throughout the astronomy community. RSI has proposed to use instead of the Triangle 6 paint a powder coating process perceived to have advantages in durability, uniformity, and cost. When first proposed in 1991, NRAO commissioned RF tests which showed that the loss characteristics of the powder coating was satisfactory. [Ref: "The Determination of the Power Reflection Spectra of Some Painted Aluminum Sheets", National Physical Laboratory Report C15/0089, Middlesex, England, December 1991.] However, RSI found that the curing process for the powder coating, which required heating the surface panels to approximately 400 F, resulted in unacceptable distortion of the manufactured panels. The subject was dropped until January 1995, when RSI requested reconsideration of the subject because they had successfully refined the powder coating materials and curing process, allowing lower curing temperatures of 235 F. The curing process now is claimed to degrade the panel RMS by approximately 0.001 inches.

One characteristic known to be true of the Triangle paint is its ability to diffuse solar radiation to reduce focal point heating. The powder coating is noticeably more glossy to the eye although it does exhibit a mild "crinkled" appearance. It was felt that the textured finish would successfully diffuse the solar radiation, but no measurements had been done to confirm this claim. Since solar astronomy is one possible application of the GBT, we undertook to compare the solar diffusion properties of reflectors finished with the Triangle 6 paint and the powder coating.

Another characteristic of painted surface panels of interest is how the panels cool when exposed to clear night skies and heat under full sun. A comparison of this property for the two surface coatings was also attempted.

2.0 Measurement Results

The approach adopted to compare the solar diffusion was to measure and compare the heating at the focal point of a bare reflector and of reflectors finished with the two coatings under consideration. Three 18 inch diameter paraboloid reflectors were purchased (Figure 1). A bare aluminum disk, 1.2 inches diameter and 0.25 inches thick, and a RTD temperature sensor were mounted at the focal points of the reflectors. The temperature sensors are specified to match to +/- 2 C from -200 C to +230 C. The temperatures were recorded as the reflectors were pointed at the sun on clear days.

The first experiment was to compare the temperatures of the three bare aluminum reflectors. There was some variation in the reflectors and the two that matched the best (about 4%) were sent off to be painted.

2.1 Scaling of Focal Heating, Bare Reflector

Tests were done on a bare reflector to determine the equilibrium focal temperature for various aperture sizes. The following table gives the aperture diameter, the approximate collecting area (taking into account the central blockage of approximately 5 cm diameter), and the equilibrium temperature. The tests were done from 14:40 to 15:40 EST March 10, 1995.

Dia in(cm)	Area cm2	Temp C
4 (10)	61	74
8 (20)	304	160
12(30)	710	295

The temperature sensor failed at approximately 330 C with the full 18 inch aperture.

2.2 Comparison of Painted and Bare Reflectors

When the painted reflectors were received, the three reflectors were mounted on a bar and aligned such that all three could be pointed at the sun simultaneously. The bare reflector was stopped down to an 8" diameter; the painted reflectors were measured with the full 18" diameter. Figure 2 shows the results, taken on April 3, 1995 beginning at 10:21 EST. The bare reflector focal temperature stabilized at 189 C, the powder coated at 33 C, and the Triangle painted reflector at 31.3 C. Figure 3 expands the scale showing the data for the painted reflectors more clearly.

The focal assemblies on the powder coated and Triangle painted reflectors were then interchanged. In addition, the aluminum focal sensor disk on the bare reflector was replaced with an identical disk with the exposed side painted with the Triangle paint. Again the three reflectors were pointed at the sun simultaneously. Figures 4 and 5 give these results. From these two tests, it can be seen that the powder coated reflector's focal temperature consistently increases about 2 C more than the Triangle painted reflector. Measured from absolute zero, the extra increase is less than 1%, which is less than the difference in heating before the reflectors were painted.

2.3 Scaling of Focal Heating, Painted Reflector

On April 5, tests were done to attempt to determine how the equilibrium focal temperature of the powder coated reflector varied with collecting area. Figure 6 shows three data sets on the same reflector for three different aperture diameters. The data sets were taken in sequence (4 inch diameter first, 18 inch last), from 11:00 to 13:00 EST. As can be seen in the lower trace, the ambient temperature was increasing rapidly at the beginning, making it difficult to determine accurately the temperature increase on the smallest diameter.

2.4 Panel Heating

In order to compare the painted reflector cooling to clear night skies, the temperature sensors were moved from the focal point to spots free of paint on the underside of the reflectors. The three reflectors were mounted about 4 feet above grassy ground and pointed at the zenith. A fourth air sensor was located near to and underneath one of the reflectors but not in contact with any surface. (In the laboratory, all four sensors agreed within 0.8 C at 24 C.) The four temperatures were recorded each minute from about 17:43 EST on 4/5/95 until about 10:00 EST on 4/7/95, as shown in Figures 7 and 8. Figures 9 and 10 show the data during the two nighttime periods with expanded scales, and Figure 11 shows the data around sundown on 4/6/95. Both nights and the intervening day were mostly clear, but the data for the early morning hours of 4/7/95 indicates there may have been some spotty clouds or ground fog around.

3.0 Discussion and Recommendations

The RSI powder surface finish appears to be slightly less efficient at diffusing the solar radiation, but only a few percent at the most. To the extent a surface finish scatters incident solar radiation uniformly about the hemisphere above the surface, heating at a painted paraboloid's focal point should scale according to the opening angle of the reflector from the focus. The GBT main reflector opening angle is 78 degrees, roughly equivalent to the 8" reflector test of 2.3. Taken with the results of 2.2, it appears that focal heating will not be a significant problem under normal conditions with either surface paint tested here.

It has been pointed out that under certain conditions (such as a thin coating of ice on the surface), the scattering effect of either paint could be nullified. Since the solar energy falling on the collecting area of the GBT can be in excess of 8 megawatts, there will always be some safety concerns. Therefore, it is recommended that the GBT control software have some built-in safeguards to warn of the main beam approaching the sun. It is also worth noting that the "paint-free" spots requested on the GBT surface panels for use by the NRAO panel setting tools totals to a collecting area of more than 1 square meter, and could be troublesome if highly reflective.

The panel heating tests showed no significant difference in the characteristics of the two painted reflectors, nor between the painted and the bare polished aluminum reflector. All three cooled below the ambient air temperature during the clear nights and heated slightly above the ambient air temperature under full sun.

In conclusion, there appears to be no reason to rule out the use of the powder paint coating on the GBT surface panels on the basis of these tests.

4.0 Acknowledgements

Jay Lockman did most of the thinking on how to interpret the test results. Brian Crouse and Bob Simmons helped in collecting the data and plotting the results.

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Barrington, NJ 08007-1380, USA

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INFORMATION AND INSTRUCTIONS

18" PARABOLIC REFLECTOR - ALUMINUM

Stock # 80,254

The paraboloid reflector you have just purchased was originally designed to concentrate solar energy for the operation of a model heat engine.

It is made of spun aluminum .93mm (.040 inch) thick. It has a diameter of 455mm (17.91 inch) and is stiffened by a turned-over rim. The focal length of the paraboloid is 114mm (4.5 inch). There is a 28.6mm (1.125") center hole.

The reflecting surface is natural aluminum. Its finish and the accuracy of curvature are not designed for imaging.

Use it as a solar heat concentrator, for the reflecting element of a directional microphone or for experimental radar antennas, traffic radar receiver antennas, or any place where a large diameter parabolic reflector is needed.

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FIGURE 1

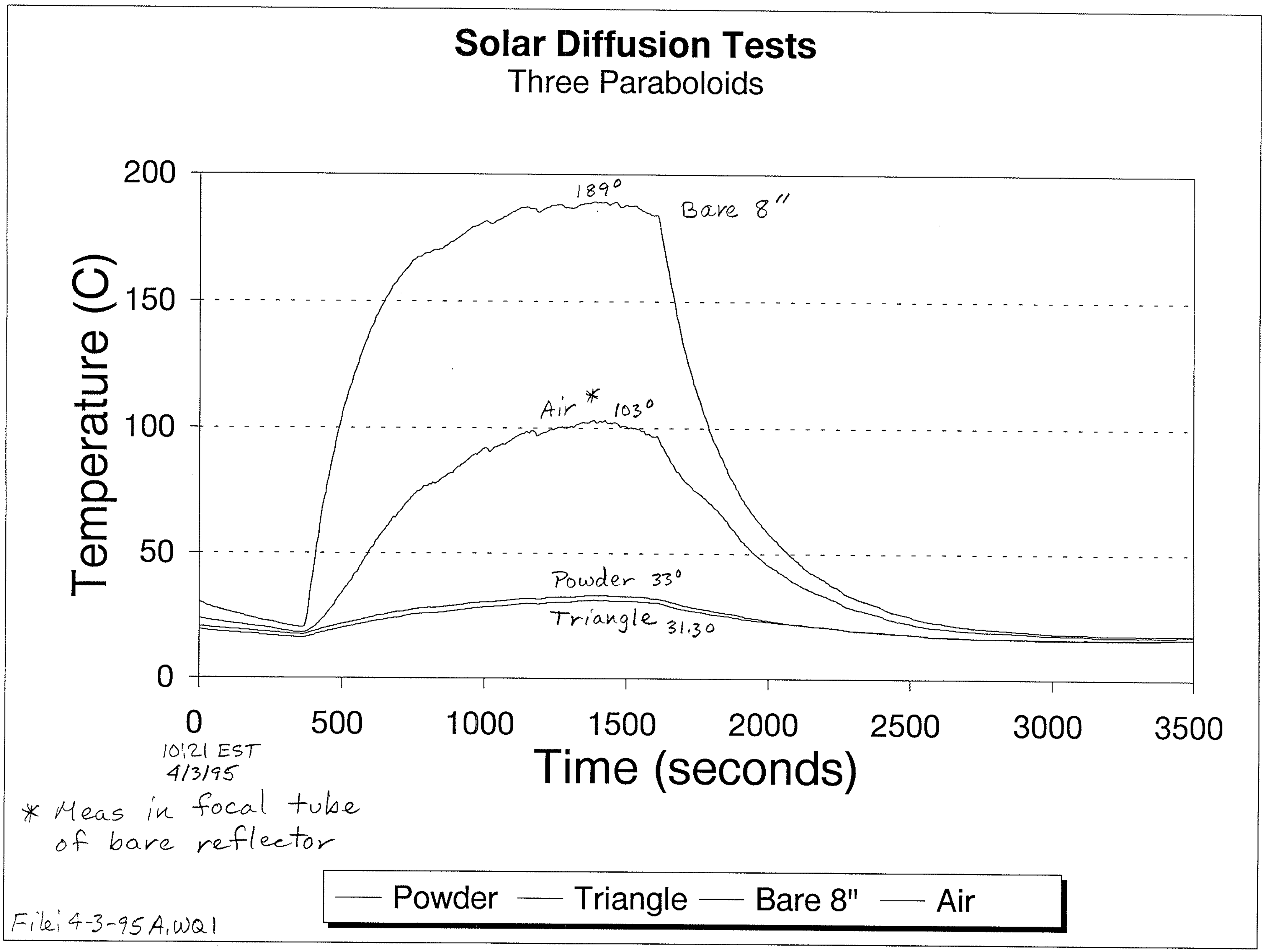

Solar Diffusion Tests
Three Paraboloids
Temperature (C)
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)
189°
Bare 8"
Air * 103°
Powder 33°
Triangle 31.30
10:21 EST
4/3/95
* Meas in focal tube
of bare reflector
Powder
Triangle
Bare 8"
Air
File: 4-3-95A.WQ1

FIGURE 2

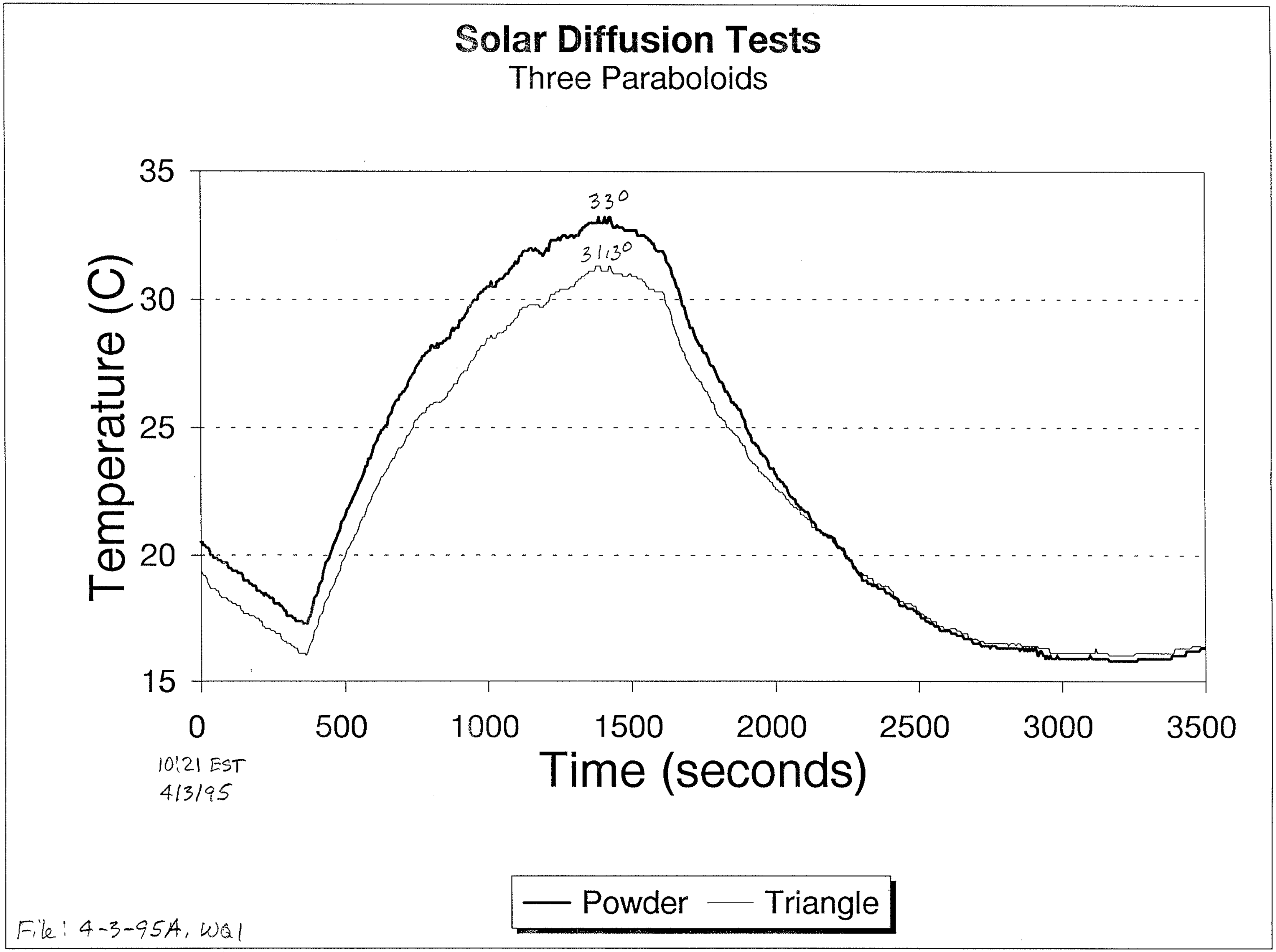

Solar Diffusion Tests
Three Paraboloids
Temperature (C)
35
30
25
20
15
0
500
1000
1500
2000
2500
3000
3500
Time (seconds)
33°
31.3°
10:21 EST
4/3/95
Powder
Triangle
File: 4-3-95A, WQ1

FIGURE 3

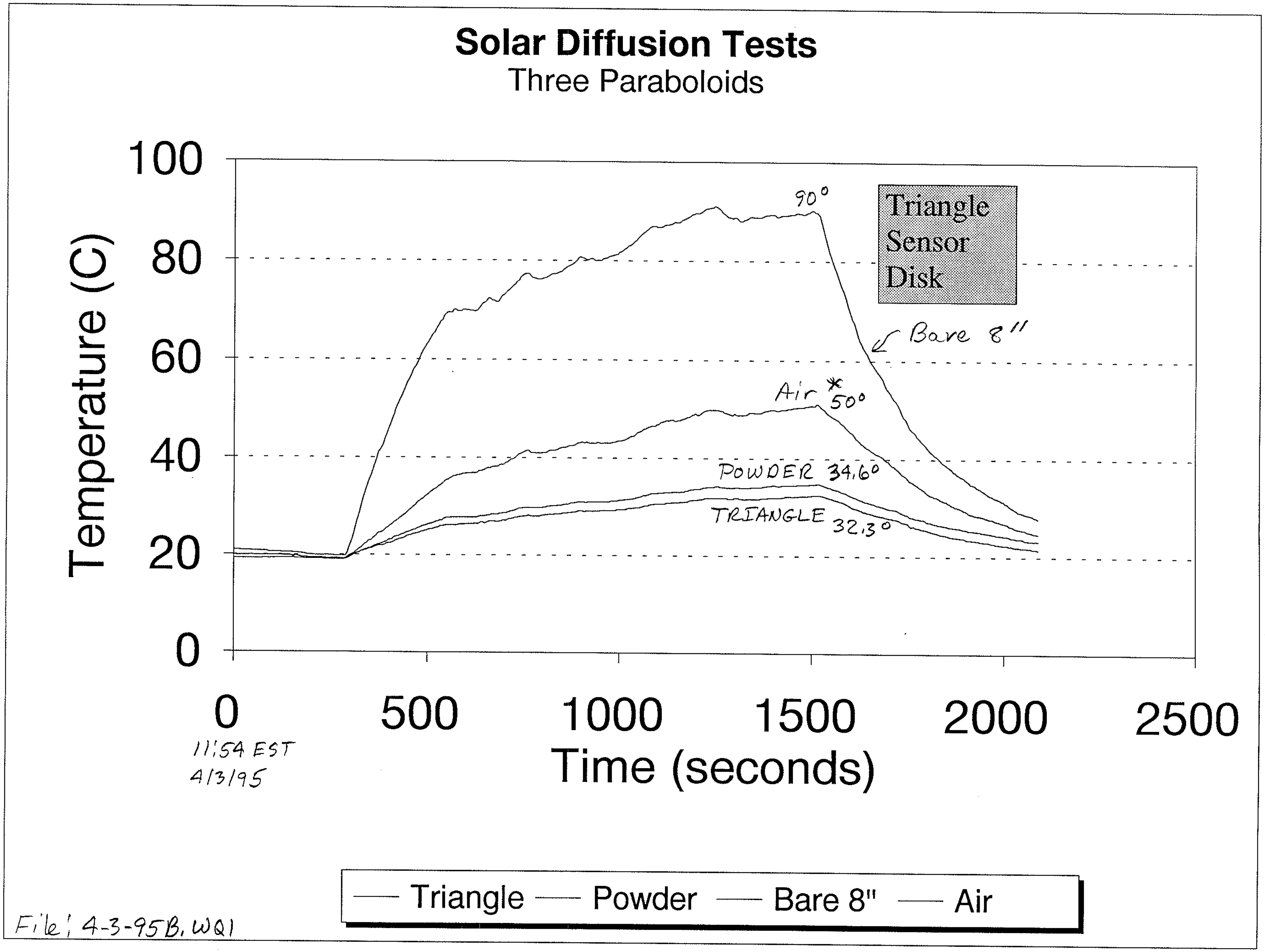

Solar Diffusion Tests
Three Paraboloids
Temperature (C)
100
80
60
40
20
0
0
500
1000
1500
2000
2500
Time (seconds)
11:54 EST
4/3/95
Triangle
Sensor
Disk
90°
Bare 8"
Air * 50°
POWDER 34.6°
TRIANGLE 32.3°
Triangle
Powder
Bare 8"
Air
File: 4-3-95B.WQ1

FIGURE 4

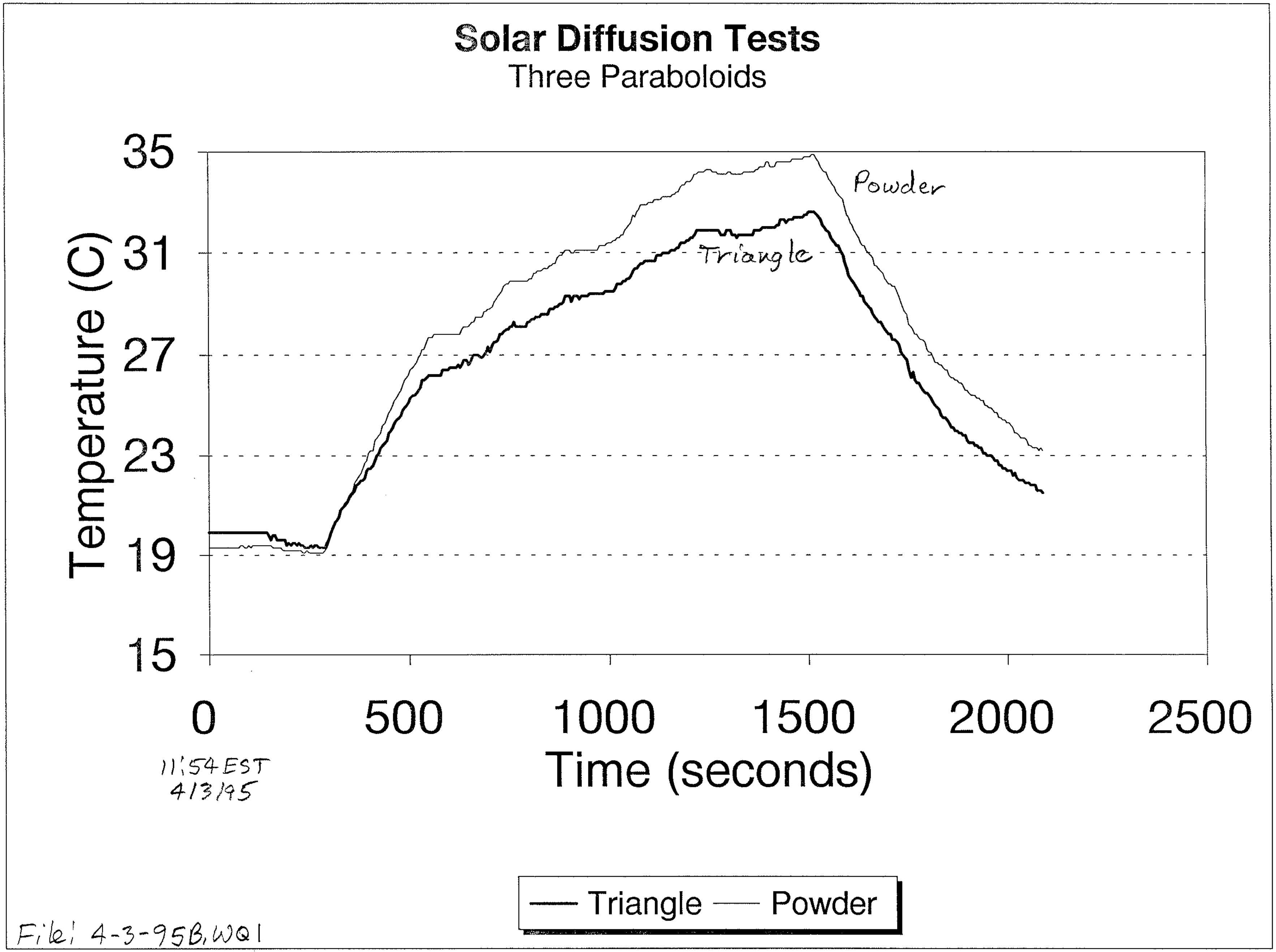

Solar Diffusion Tests
Three Paraboloids
Temperature (C)
35
31
27
23
19
15
0
500
1000
1500
2000
2500
Time (seconds)
Powder
Triangle
11:54 EST
4/13/95
Triangle
Powder
File: 4-3-95B.WQ1

FIGURE 5

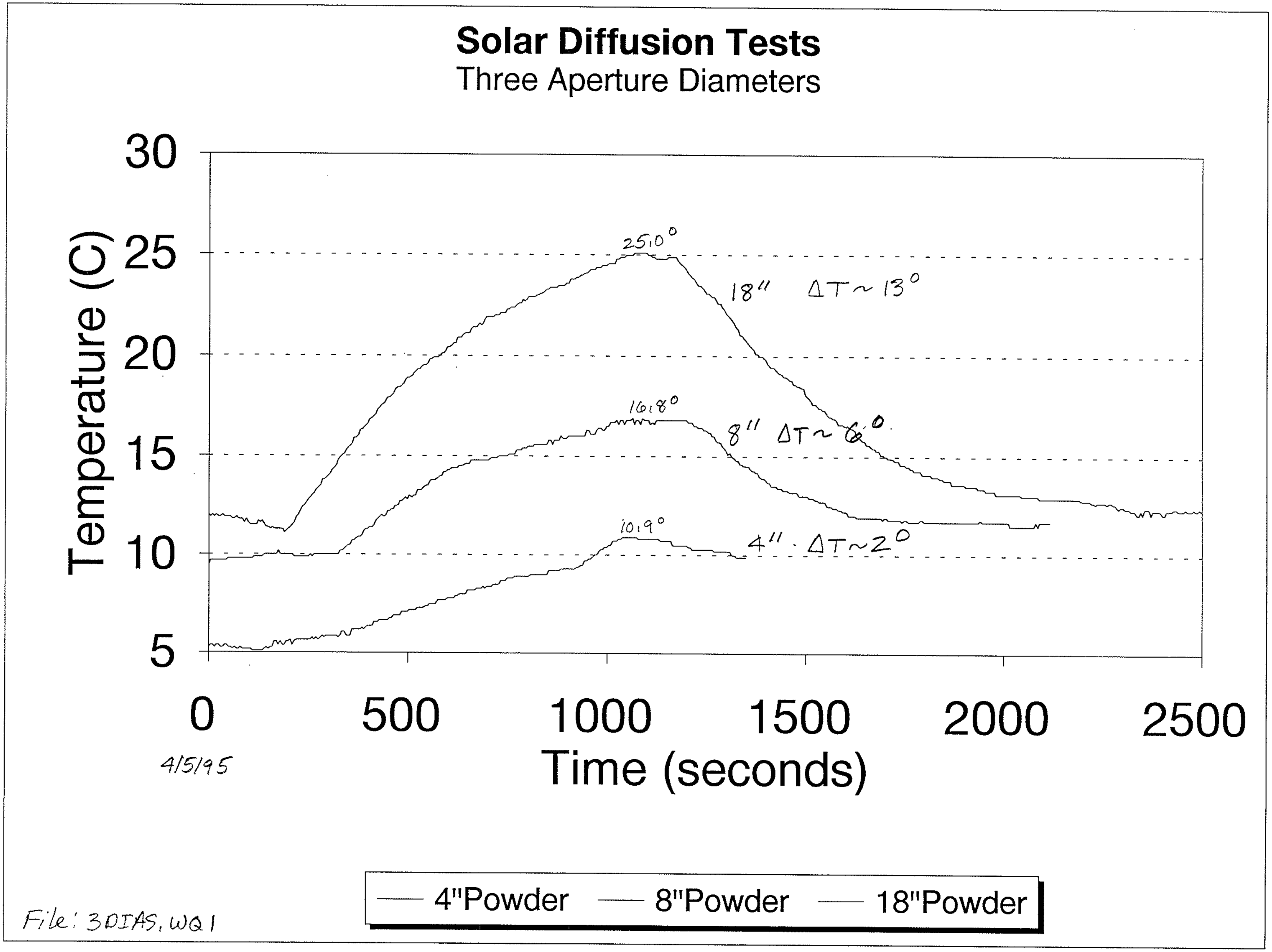

Solar Diffusion Tests
Three Aperture Diameters
Temperature (C)
30
25
20
15
10
5
0
500
1000
1500
2000
2500
Time (seconds)
25.0°
18" ΔT~13°
16.8°
8" ΔT~6°
10.9°
4" ΔT~2°
4/5/95
File: 3DIAS.WQ1
4"Powder
8"Powder
18"Powder

FIGURE 6

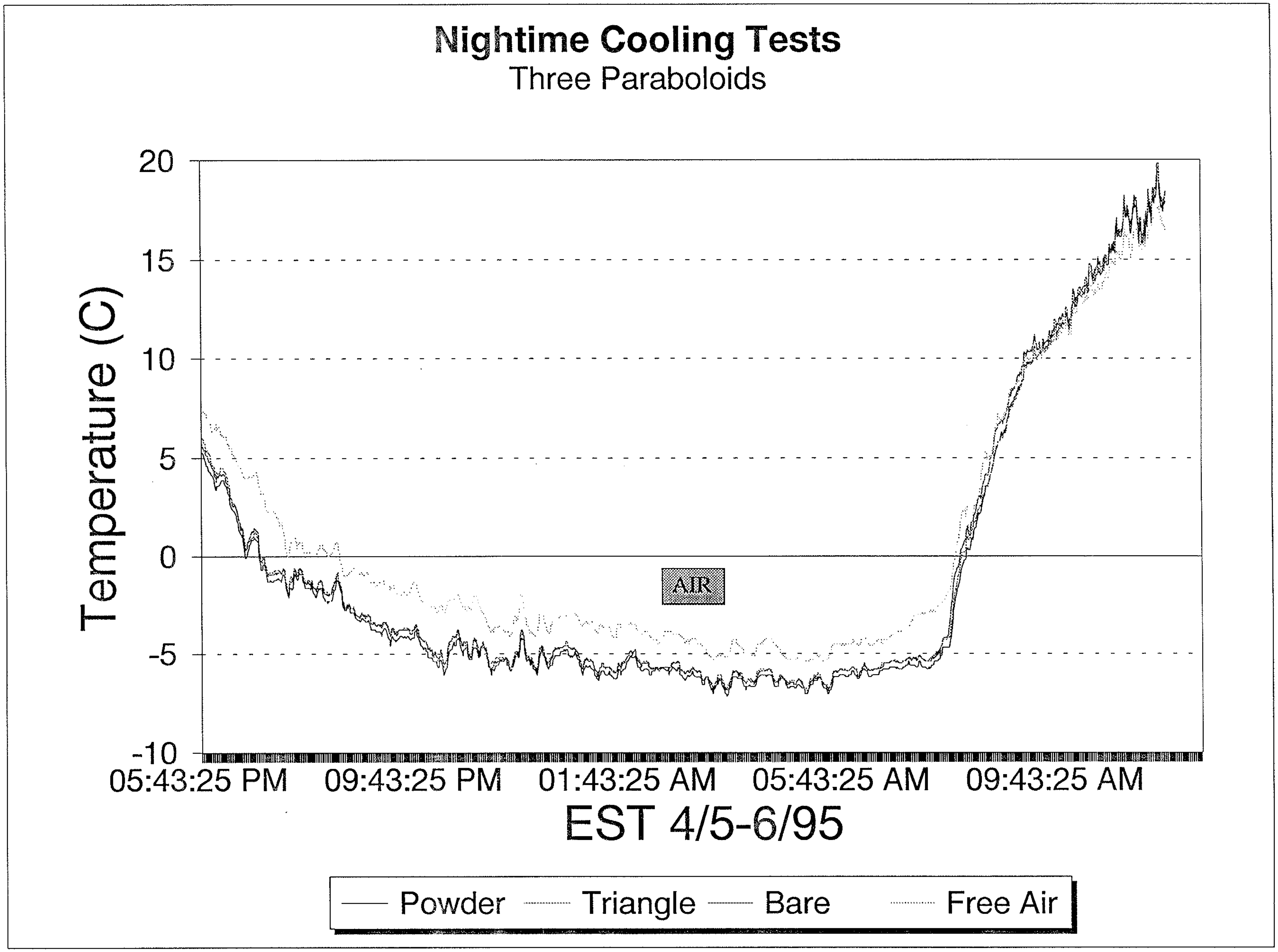

Nightime Cooling Tests
Three Paraboloids
Temperature (C)
20
15
10
5
0
-5
-10
AIR
05:43:25 PM
09:43:25 PM
01:43:25 AM
05:43:25 AM
09:43:25 AM
EST 4/5-6/95
Powder
Triangle
Bare
Free Air

FIGURE 7

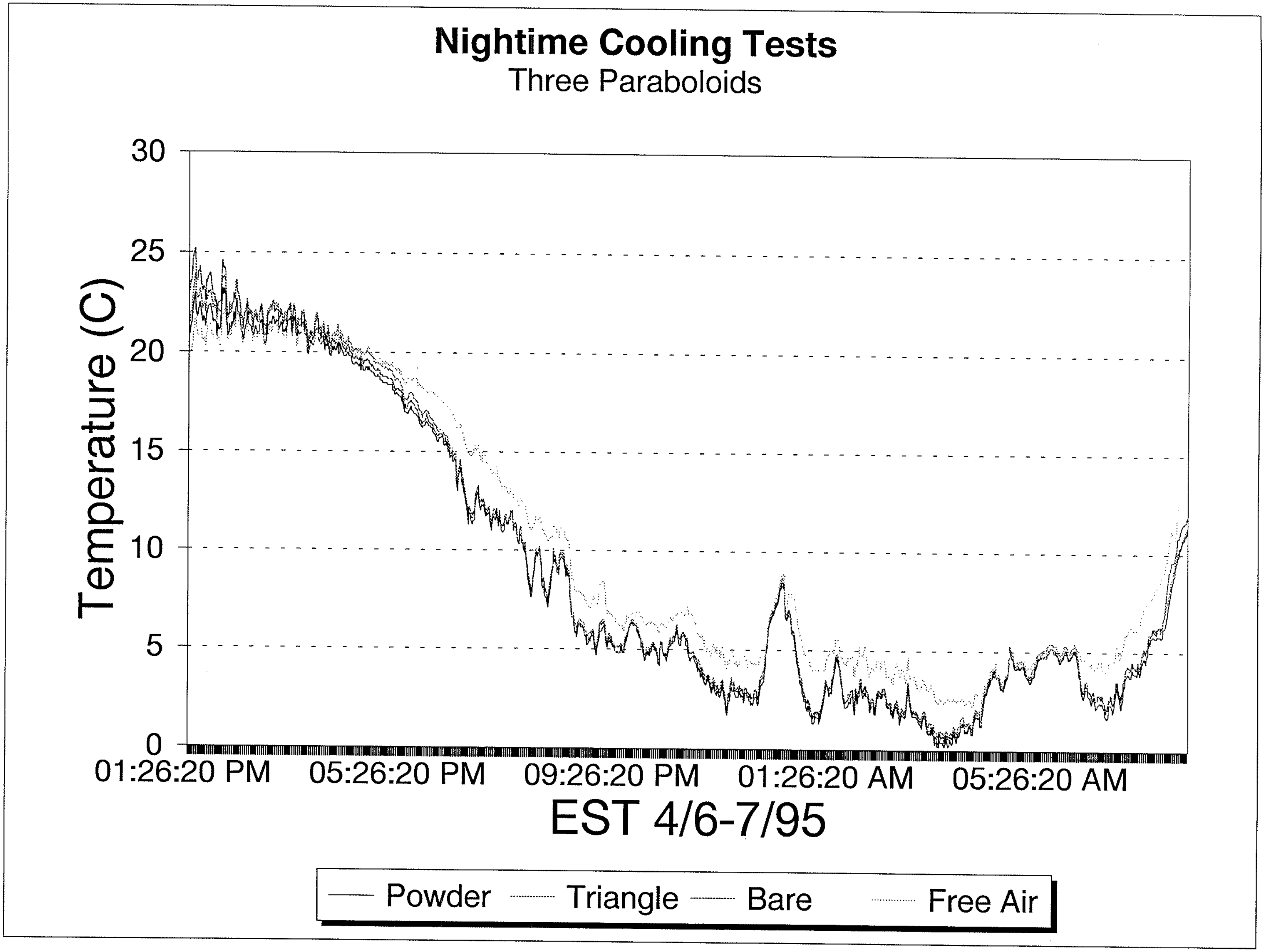
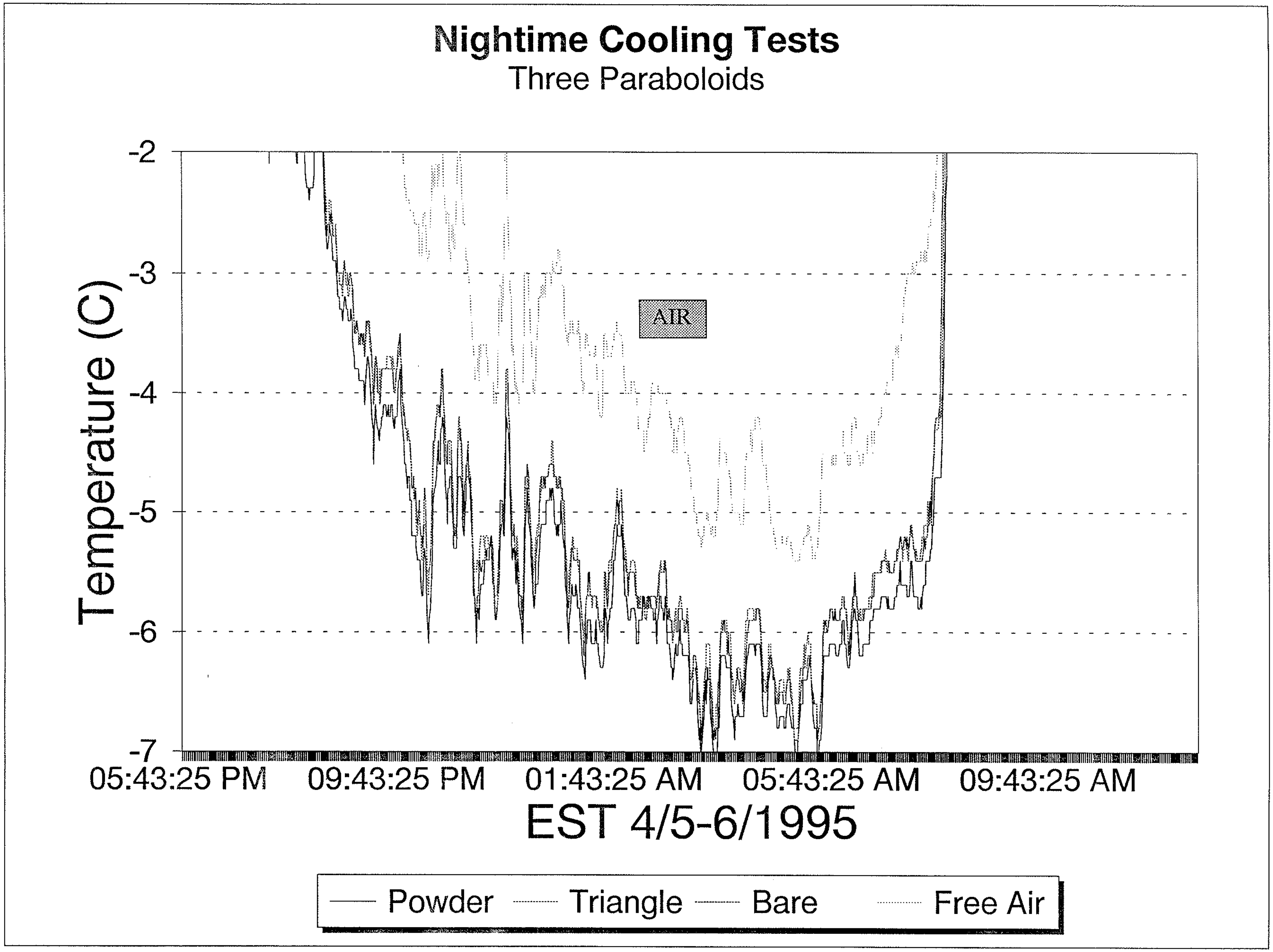

Nightime Cooling Tests
Three Paraboloids
Temperature (C)
30
25
20
15
10
5
0
01:26:20 PM
05:26:20 PM
09:26:20 PM
01:26:20 AM
05:26:20 AM
EST 4/6-7/95
Powder
Triangle
Bare
Free Air

FIGURE 8



Nightime Cooling Tests
Three Paraboloids
Temperature (C)
-2
-3
-4
-5
-6
-7
AIR
05:43:25 PM
09:43:25 PM
01:43:25 AM
05:43:25 AM
09:43:25 AM
EST 4/5-6/1995
Powder
Triangle
Bare
Free Air

FIGURE 9

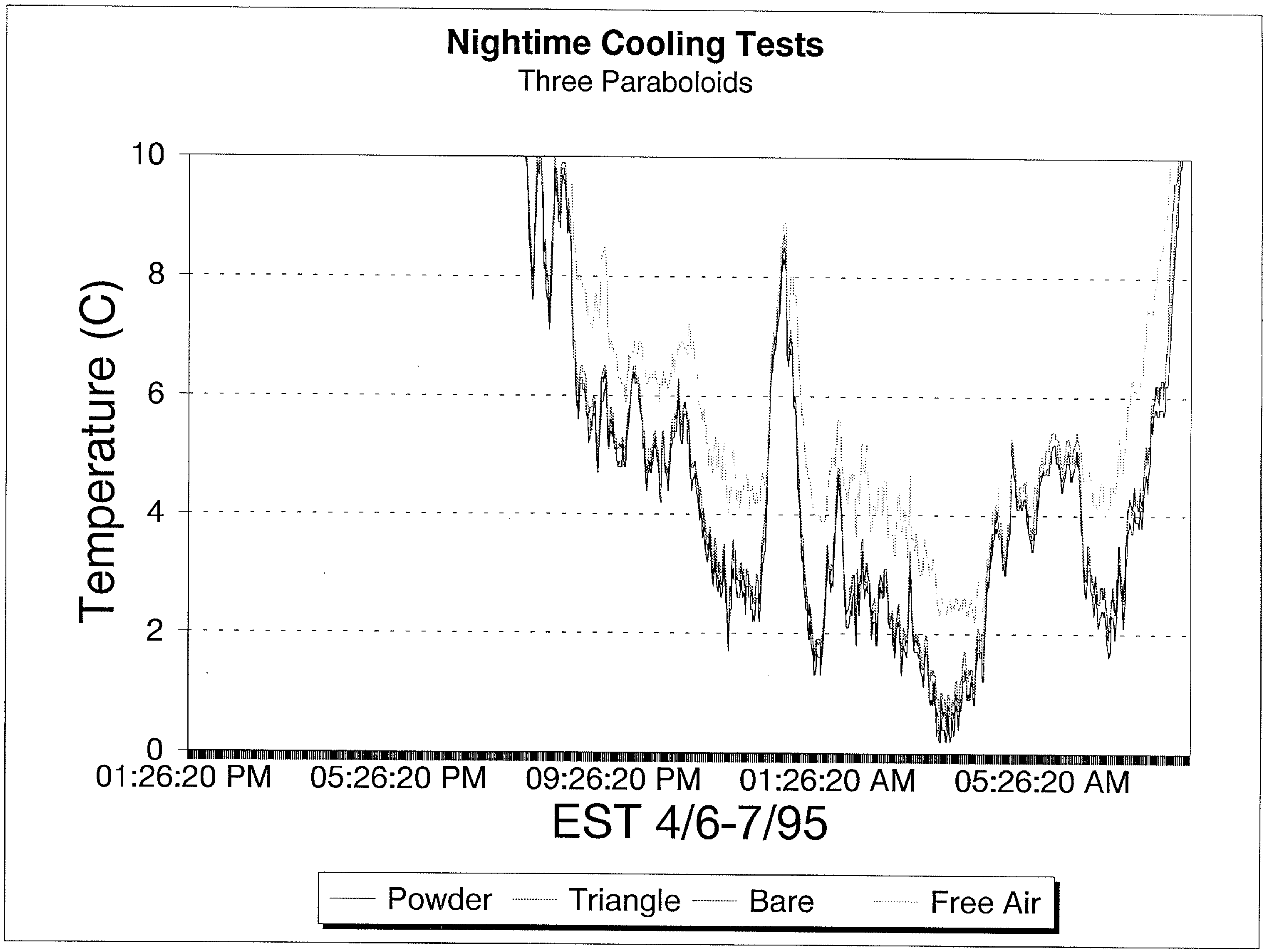

Nightime Cooling Tests
Three Paraboloids
Temperature (C)
10
8
6
4
2
0
01:26:20 PM
05:26:20 PM
09:26:20 PM
01:26:20 AM
05:26:20 AM
EST 4/6-7/95
Powder
Triangle
Bare
Free Air

FIGURE 10

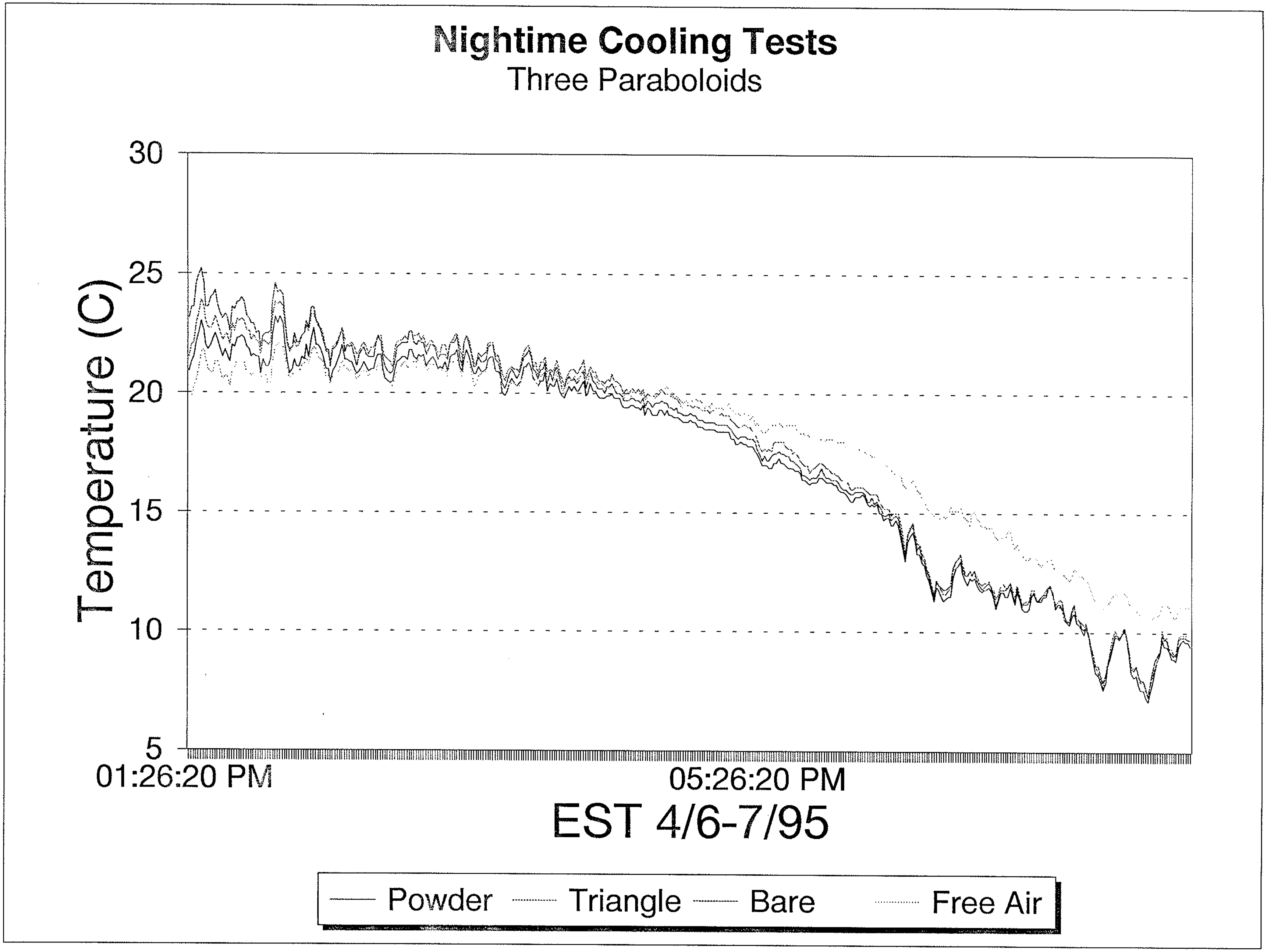

Nightime Cooling Tests
Three Paraboloids
Temperature (C)
30
25
20
15
10
5
01:26:20 PM
05:26:20 PM
EST 4/6-7/95
Powder
Triangle
Bare
Free Air

FIGURE 11